forest products utilization research priorities in the northeast

a report prepared for the northeastern regional planning committee

northeastern forestry committee
forest products utilization subcommittee

RP 2.04

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PREFACE

This research planning report was prepared as part of the Regional and National Agricultural and Forestry Research Planning System. The mission of this System is:

1. To further the research effectiveness of scientific talent and other research resources and,

2. To improve coordination between Federal, state, and private research organizations.

Research planning reports were prepared for fifteen forestry research subject areas. The reports will help accomplish the mission of the Planning System by helping:

1. to guide forestry research to the highest priority needs;

2. to avoid duplication of research efforts;

3. to coordinate research findings and to build on interim research results;

4. to assure recognition of emerging problems;

5. to provide advance information for adjusting research capability to research needs.

The subjects of the fifteen reports are:

2.01 Forest Inventory
2.02 Timber Management
2.03 Forest Insects
2.03 Forest Diseases
2.03 Forest Fire
2.04 Timber Harvesting
2.04 Forest Products Marketing
2.04 Forest Products Utilization
2.05 Forest Soils
2.05 Forest & Water Relationships
2.05 Forest & Air Relationships
2.06 Wildlife & Fisheries Habitat
2.07 Forest Recreation
2.08 Forest Land Use
2.09 Forest Economics, Policies, and Programs

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED) Page Nos.

I. LIST OF SUBCOMMITTEE MEMBERS

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II. SUMMARY TABLE OF PROPOSED RESEARCH

Titles	Degree of Difficulty	Study Term	Information: Source	Information: Adequacy	Personnel Needs	Research Benefactor	Benefits: Direct	Benefits: Indirect	Risk: Objectives	Risk: Use	Priority
A. Basic properties	H	L	E,F,L	M	15	S,I	M	H	M	H	H
B. New & improved products-modification											
1. Fire retardancy	H	L	E,F,L	M	7	I	H	M	H	H	H
2. Weathering-coatings & overlays	M	S	E,F,L	M	3	I,C	M	L	H	M	L
3. Dimensional stabilization	H	S	E,L	M	5	I,C	M	L	L	L	L
4. Preservation	M	L	E,F,L	M	5	I	H	H	M	M	M
C. Composites											
1. Flake, particle, fiberboard	M	S	E,F,L	M	5	I	H	H	H	H	M
2. Laminated beams and columns	L	S	E,F,L	M	4	I	H	M	H	M	M
3. Laminated lumber	L	S	E,L	M	3	I	M	M	H	L	M
4. Molded products	H	S	E,F,L	M	6	I	M	M	H	M	M
5. Wood composites	M	L	E,F,L	L	3	I	M	M	M	M	L
D. Components											
1. Fastening methods	M	L	E,F,L	M	3	I	M	M	M	H	M
2. Optimizing building materials	M	L	E,F,L	M	7	I	M	M	H	M	M
3. Heat transmissions	M	S	E,F,L	M	5	I,C	H	M	H	H	M
4. Sound transmission	M	S	E,F,L	M	4	C	H	M	H	H	H
E. Fabricated products											
1. Low-grade lumber utilization	M	L	E,F,L	M	4	I	H	M	H	H	M
F. Residue utilization											
1. Urban wood waste	M	S	E,F,L	M	6	I,C	M	M	H	H	L
G. Chemicals from wood											
1. Chemicals from wood	H	L	E,F,L	M	12	I,C	M	H	H	H	H
H. Improved processing											
1. Classification of logs & lumber	M	L	E,F,L	M	3	I	M	M	H	M	M
2. Improved processing techniques	M	L	E,F,L	M	6	I	H	M	H	H	H
3. Improved milling & machining	H	L	E,F,L	M	9	I,C,S	H	H	M	H	H
4. Improved drying	M	L	E,F,L	M	7	I	H	M	M	H	H

GUIDE TO SUMMARY TABLE OF PROPOSED RESEARCH

Title	Degree of Difficulty	Study Term	Information Source/Adequacy	Personnel Needs	Research Benefactor	Benefits Direct/Indirect	Risk Objectives/Use	Priority
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)

(a) Title of research need

(b) Degree of difficulty (an assessment by members of the research planning group) - designate High (H), Moderate (M), or Low (L).

High: complex, multi-objectives, multi-disciplinary requiring senior scientist direct, multi-person support and high operating budget.

Moderate: single objective, junior scientist supervision, moderate operating budget, one or two person support staff.

Low: single objective, junior scientist supervision, low operating budget.

(c) Study term: 5-year period or less is considered short term (s), anything greater is long term (L).

(d) Information needed: The research may be of the type which requires inventory and interpretation of existing data (E), field studies (F), laboratory studies (L), or any combination of these three. Use (O) for other if E, F, or L do not apply and explain (O) in a footnote. The adequacy of existing information can be shown as High (H), Medium (M), or Low(L).

(e) Personnel needs: Show number of Scientist Man Years. (SMY's) required for the research (SMY's are an indicator of both cost and time requirements).

(f) Research Benefactor: Show whether the major recipient and user of the research is: other Scientists (S), Federal Agencies (F), Other Public Agencies (P), Industry (I), the Public (C), or some other group (O).

(g) Benefits:
Direct benefits are -
High (H) where the results have immediate impact, are direct, and require little further work and synthesis. Medium (M) benefit is obtained from solutions to problems of lower priority, perhaps with an impact to small segments of the audience. Additional work is required to gain broader application. Low (L) benefit accrues to lower priority items or items which are very restricted in use, perhaps parochial. They may be one of a series of studies and require additional work or may be exploratory in nature.

Indirect benefits can also be shown as -
High (H), Medium (M), or Low (L). Strength of indirect benefits is indicated by such things as the potential use of this research to solve other problems, or use of the results as part of a broader, multi-resource type of problem.

(h) Likelihood of Success:
Both elements of this item can be classified as High (H), Medium (M), or Low (L). Objectives refers to the probability of reaching the objectives of the research. Use refers to the extent and likelihood that the research results will in fact be used.

(i) Priority: This is an overall research priority rating based on evaluation of all other elements in this table. Again, the priority should be shown as High (H), Medium (M), and Low (L).

III. INTRODUCTION

From the spruce fir region of northern Maine to the oak-yellow poplar forest type of southern West Virginia, the Northeast Region contains an abundance of forest land. Particularly along the coast, the Northeast Region also contains an abundance of people. It is a challenge to utilization research to maximize the benefits to the people from the harvesting of this forest land. It is recognized that a large proportion of the resource is not currently in high demand but has excellent use potential.

In spite of the large quantity of trees in this region, much of the wood, fiber, and energy consumed in the Northeast is imported to the area. By the year 2000, predicted shortages in the supply of these raw materials suggest the need for the Northeast to become more self sufficient. Utilization research leading to the more complete use of what is available is, therefore, very necessary. Conventional conversion methods often result in misallocation of resources and waste in many of the manufacturing steps from the log to the finished product. A more efficient and more complete utilization of our renewable wood resource is required if we are to continue to enjoy our current standard of living.

Within the concept of sustained forest yield, there are ample utilization opportunities. The current rate of tree growth is many times greater than the amount being removed. The forests are close to major markets. In general, transportation is adequate and a supply of labor exists. Work must be done with considerations of environmental constraints and with the aim that the final products will contribute effectively to shelter, energy conservation, and other needs.

IV. BROAD PROGRAM AREAS OF RESEARCH

A. Basic properties and fundamental relationships

1. Title: Basic properties and fundamental relationships

Objective: To characterize and evaluate Northeastern forest trees and tree-derived residues as raw materials.

Situation evaluation: We can no longer afford the luxury of inefficient and wasteful utilization practices. The future demands a more complete use of our forest resource. This includes relatively unused species; unused tree portions such as branchwood, rootwood, and bark; and urban lignocellulosic residues such as discard paper and wood products. In order to accomplish an increase in efficient utilization, it is necessary to precisely and accurately establish the basic raw material properties of the various tree components and urban residues.

To fully and efficiently utilize our wood based materials, in addition to ascertaining their basic properties, it is also necessary to gain a more complete understanding of how these materials are grown and the nature of their performance in response to external conditions. For example, studies of the relationship of growth variables and tree material formation could lead to faster growing, more productive and higher quality sources of tree material. Also, by studying factors affecting material performance; such as moisture movement, improved processing and products could result.

Increased and full use of our wood based materials is dependent on the development of new and improved products needed in our society. In order to evaluate the technological feasibility of products, it is necessary to understand the factors affecting the processing as well as the finished product. Studies on the relationship between raw material variables, processing, and product qualities should result in this needed understanding.

Research priorities:

1. A more complete study and characterization of the raw material properties of Northeastern tree species, tree components, and woody residues are needed. Special emphasis should be placed on trees and residues that are currently being underutilized.

2. More research is needed to evaluate the feasibility of using various cellulosic materials for new and improved products. Raw material variables must be related to product variables under a wide range of environmental conditions.

Research approach: In order to obtain the basic data needed to accomplish the research objective, three broad facets of study are needed. First, the basic properties of the material must be determined over a wide range of environmental conditions. Second, the material response to various combinations of external inputs must be studied in order to gain an understanding of the fundamental mechanisms of formation and performance unique to the material. Finally, in order to evaluate the feasibility of the material for products, it will be necessary to study various raw material-product relationships over a wide range of conditions.

The characterization of our forest trees as a raw material would include a more definitive establishment of various properties of different tree portions including branchwood, stemwood, and rootwood. Other tree components such as needles, leaves, bark, and exudates would also be investigated. Properties to be studied would include anatomical, structural, physical, chemical, mechanical, and nutritional. The studies would be conducted over a wide range of conditions of moisture content, temperature, and pressure. The material to be investigated would range in size from the basic cellular components on up to structural-size specimens. The total population of forest trees would be sampled regardless of current commercial classification and inter- and intra-species variability would be assessed.

The amount and characteristics of urban lignocellulosic residues also need to be investigated as a possible raw material. Various properties of these residues would also be determined with particular emphasis on their fuel value, chemical feedstock value, and reconstitutability.

As a means of gaining a fuller understanding of mechanisms of growth and performance of the material, its response to varying external stimuli should be studied. The effect of various growth parameters on material properties, especially the anatomical, structural, and chemical, would be investigated. Research would also be conducted on the reaction of the material to varying types of external conditions including varying combinations of high temperature, pressure, and moisture content. The response of the material to varying types of gaseous and liquid environments would also be studied.

One of the recommended methods of studying raw material-product relationships would be by varying raw material parameters and noting their effect on product properties. These studies would include the effect of ply, particle, chip, and/or fiber on various reconstituted products. The use of operations research methods for such purposes as simulation would also be studied.

B. New and improved products - modification

1. Title: Fire retardancy

Objective: To improve the fire resistance and the safety in a fire of wood-based products

Situation evaluation: At the present time there is a strong emphasis on adhering to limits of Flame Spread as measured using a 25-foot tunnel furnace as specified by ASTM E 84-67 for materials used in building interiors. The emphasis on smoke and gas evolution is much less although considerable evidence has accumulated to indicate that these two factors may cause more fatalities in fires than burning caused by spreading flames. A building may become smoke- or gas-filled in a matter of minutes trapping people inside the structure due to decreased visibility, suffocation, or toxification. There are many fire retardants in use today that retard flame spread at the expense of increased smoke and possibly noxious gases. There is a need to measure smoke evolution and to quantify and identify gases given off by burning wood, floor or ceiling coverings, paints, finishes, coverings for furniture, and to evaluate fire retardants as to these properties. There is a need to consider all of the components and room contents of a building as a system in an attempt to relate the various small scale tests now used to actual fire performance in a burning building.

Research approach: Additional work is required to evaluate smoke evolution by wood, fire retardant treated wood, floor and ceiling coverings, paints, furniture coverings, and polymers used in furniture manufacturing. An attempt is needed to consider all aspects of the problem by investigation of a burning building as a system. Small scale tests should be related to burning buildings. There may be many opportunities for performance of large-scale tests on buildings scheduled to be razed, similar to tests which have been made in Canada, Wisconsin, and California, but specifically monitored to determine and record smoke conditions and gas evolution.

It may be possible to utilize gas chromatography for the identification of gases given off when certain polymers, treated woods, or paints are burned.

2. Title: Weathering-coatings and overlays

Objective: To improve the performance of coatings and overlays

Situation evaluation: In the Northeast there is a general problem of paint peeling from wood exterior surfaces after a relatively short time following application. It may be related to the time of application, preparation of surface, vapor movement, and the formulation of the paint. In this part of the country the extreme changes in temperature and humidity conditions tend to increase the seriousness of this problem.

Furniture coatings are usually nitrocellulose which is highly flammable and which requires large quantities of organic solvents in manufacture with its problems of vapor recovery and fire hazard. This problem has been investigated by the industrial research groups, but their results are usually treated as proprietary information and is not published. Thus it may be difficult or unadvisable for government or educational research organizations to undertake research in this area.

Research approach: A systems approach could be applied to the problem of paint peeling from external wood surfaces. Such factors as vapor movement through walls, vapor-barrier materials, wood moisture content at time of application, and the preparation of the surface need consideration. The adhesive bond at the interface could be examined using the tools of electron microscopy and X-ray analysis. The formulation of exterior paints should be investigated from the point of view of developing an improved adherence to the substrate and adequate breathing characteristics to permit moisture to diffuse through rather than become trapped under the surface.

3. Title: Dimensional stabilization

Objective: To decrease the dimensional changes in wood and wood products in response to changes in moisture content

Situation evaluation: One of the principal disadvantages of wood and wood products is swelling and shrinking due to change in moisture content and the resulting stresses and warp. These effects are greatly reduced in plywood due to the right angle grain orientation of the plies and in wood treated with polyethylene glycol. The latter process is slow, expensive, results in greatly increased weight, and produces a product difficult to finish. Many of the chemical and heat treatments increase stability at the expense of decreased mechanical strength and degraded structure. The introduction of

wood-polymer composites has greatly decreased the dimensional changes over relatively short time spans due to the significantly reduced rate of moisture diffusion through the cell wall (approximately one-tenth the rate in untreated wood). This is sufficient for many specialty applications such as archery bow handles, golf club heads, bagpipe chanters, and flooring. The monomers used to not penetrate the cell wall, and thus the cell walls can become saturated with moisture and swell if allowed sufficient time. In addition, wood-polymer parts have only been made in small sizes; and the size limitations for this material are not known.

Research approaches: Research efforts could be directed toward the development or evaluation of monomer systems which can be carried into the cell wall. It would be most desirable if a treatment could be found which would bulk the cell wall only while leaving the pits, vessels, and lumens open to permit subsequent liquid or preservative treatments. This would necessitate the use of a monomer with polar properties which would permit it to bond to the water sorption sites of the cell wall. Another possibility would be to do additional work on carrying nonpolar monomer molecules into the cell wall by dissolving in polar solvents such as ethanol or dioxane. The material may then be polymerized *in situ* and the solvent evaporated. This process has possibilities but needs further evaluation.

The use of wood polymers is limited to articles of relatively small size, and it is not known what the size limitations are. The exothermic heat resulting from polymerication must be dissipated through the surfaces of the specimen, and this requirement may limit the size of specimen which may be treated. In addition to this, the maximum penetration in different wood species would be a limitation which should be evaluated.

The improvement of wood-polymer composites is of particular interest in the Northeast since most of the species used for these composites, such as red oaks and maples, are native to this area.

4. Title: Preservation

   Objective: To increase the lifetime of Northeastern woods against wood-destroying fungi, insects, or bacteria and to improve fire performance through improved wood-preserving treatments

Situation evaluation: Most wood preservatives are carried into wood as liquids by the use of pressure treatments. Many of the Northeastern woods are difficult to treat limiting their usefulness under conditions of exposure to decay or fire. Pressure treatments are generally limited to 200 lb/in^2 in pressure and temperatures under 200°F. Research efforts could be directed toward the evaluation of high-pressure treatments of refractory species such as heartwoods of beech, elm, aspen, maple, or other Northeastern species. Of special interest is research leading to improved permeability of eastern spruce, hemlock, and larch in order that these species may be easily treated to meet the requirements of all weather wood foundations and other treated products.

The effectiveness of a wood preservative may be related to its location within the wood; that is, whether or not it has penetrated the cell wall, the distribution between heartwood and sapwood, and the distribution between earlywood and latewood.

Research approach: The effects of high-pressure impregnation of refractory Northeastern species may be evaluated by determining the effects of high pressure on liquid retention and upon collapse or other physical damage to the wood. The effect of the rate of pressure increase would be studied. The rate of flow of liquids into wood following the application of pressure would increase our knowledge of the mechanisms of unsteady-state flow during pressure treatment.

Electron microscopy may be used as a tool to locate preservatives within the cell wall, between earlywood and latewood, and between heartwood and sapwood. This may also be used to study the distribution of preservatives throughout the gross structure of the wood. It may also be possible to use neutron activation analysis to study distribution of preservatives, to determine if there is chromatographic separation of the components of water borne preservative mixtures and also to study the fixing of water borne preservatives within the cell wall.

Refractory species may become easily treatable by the use of non-pressure methods such as diffusion in which a water-borne solution enters the cell wall and proceeds through the wood by a combination of capillary movement and diffusion.

C. New and improved products - composites.

1. Title: Flakeboard, particleboard, fiberboard, and structural members.

Objective: To improve the marketability and efficient use of composite board and structural members by developing structural grades for these materials for exterior use and to examine the possibility of producing these products from low-grade Northeastern woods.

Situation evaluation: With the increasing need to harvest smaller and lower grade trees in the Northeast, there will be greater difficulty in producing high grade lumber. As an alternative to lumber production, low-grade material and residues may be chipped or flaked to flakeboards or structural members. Larger quantities of these products will need to be used in expanding markets and may find application in exterior construction. The successful production of these products from low-grade hardwoods and softwoods in the Northeast would create the demand to establish manufacturing facilities throughout this part of the country and thus help the general economy and assist in the utilization of material which is not suitable for lumber manufacture.

There are no ASTM testing standards for the structural use of these products. Therefore, adequate design information is not available to permit the efficient use of these materials in exterior construction. In addition, the aging properties and creep properties need to be determined.

The electron microscope can be used as a research tool in the analysis of fracture patterns in structural products and for the examination of glue lines and adhesive penetration.

Research approach: A pilot plant research operation has been established at the University of Massachusetts to produce flakes and chips from low grade Northeastern species similar to the investigations of hardwood utilization at the Southern Forest Experiment Station. There are many plantation softwoods such as red pine, tamarack, spruces, and soft pines as well as second-growth white pine which are of relatively small size and have a large proportion of juvenile wood making them generally unsuitable for lumber production. Experimental boards can be made from these materials which can be compared in structural properties with plywood and other panel products. Similar investigations could be launched to evaluate panel products made from low grade hardwoods or possibly from hardwoods mixed with softwoods.

Joint efforts with the appropriate subcommittee of ASTM could be directed toward the establishment of mechanical testing methods to evaluate the possible use of board products in exterior structural application. Comparisons could be made with plywood which is now used as a structural material. The aging properties can be determined by examining the effects of weather, ultra-violet exposure, water exposure, and moisture content changes upon the material. Mechanical creep characteristics may also be investigated.

2. Title: Laminated beams and columns

Objective: To study the feasibility of using woods produced in the Northeast in the manufacture of laminated beams.

Situation evaluation: There are laminated beam plants in Sidney, New York, and Billerica, Massachusetts, which use southern pine lumber in their product. There are many Northeastern species which could possibly be used for this product. Plantation grown red pine is an example. If it could be shown that Northeastern species could be used in this manner, this may encourage the establishment of additional laminated beam plants in the Northeast.

Research approach: Experimental laminated beams could be produced in a pilot-plant operation or in cooperation with existing plants and tested mechanically to compare their properties with laminated beams produced from southern pine or Douglas-fir. Special attention would be directed toward the effect of large amounts of juvenile wood in these laminated products.

3. Title: Laminated lumber.

Objective: To investigate the possible improved utilization of low-grade Northeastern woods by the production of laminated lumber.

Situation evaluation: Many of the low-grade Northeastern woods do not produce satisfactory lumber due to large numbers of knots and a high fraction of juvenile wood. The influence of these defects on the mechanical properties of lumber could be greatly diminished by lamination of veneer into lumber. Some research of this kind has been conducted at SUNY College of Environmental Science and Forestry with encouraging results. The average strength of this lumber was lower than solid wood lumber of the same size, but the standard deviation of the spread was significantly less with the weakest laminated board being stronger than the weakest solid wood board. Thus, the allowable working stresses for laminated lumber may equal or exceed those for standard lumber.

Experimental lumber can be laminated in a pilot plant having a small veneer lathe and presses for gluing. Lumber in any length can be produced by staggering the butt joints. This could create a demand for low-grade material which is not being utilized at the present time.

4. Title: Molded products.

Objective: To develop molded products from wood residues in the Northeast.

Situation evaluation: There is an increasing fraction of low-grade hardwoods in the Northeast which are too small and not of sufficiently high quality to produce lumber. In addition, residues of forest products industries would also be available as feedstock. The successful development of molded products reinforced by 3-dimensional wood particles may stimulate the establishment of plants to produce these products.

Research approach: Dr. Alan A. Marra has been conducting a research project for the development of molded products at the University of Massachusetts. This kind of work could be continued, expanded, or extended to investigate the spectrum of molded composites produced from polymers reinforced by wood fiber bundles or 3-dimensional particles. This project has been directed at the utilization of hardwoods, but it may also be advisable to attempt to produce a similar product using low-grade Northeastern softwoods.

5. Title: Composites of wood in combination with concrete, steel, or fiberglass.

Objective: To investigate properties of composite materials which can be made with wood in combination with steel, concrete, or fiberglass.

Situation evaluation: The development of new composite materials may create a demand for residues and low-grade materials which are available in increasingly large quantities.

Research approach: Experimentation with concrete mixed with wood fibers may result in a material with increased tensile strength. Sawdust may find use as an extender in concrete. There is also the possibility of reinforcing concrete using solid wood to increase the tensile strength.

There may be a possibility of improving the mechanical strength of flakeboard, particleboard, or fiberboard by the addition of fiberglass or steel reinforcement. Experimental composites of these types could be produced on a pilot-plant scale and evaluated.

D. New and improved products - components.

1. Title: Fastening methods.

Objective: To analyze the static and dynamic behavior of fastening systems.

Situation evaluation: Fastening systems are used extensively in light frame construction. A discussion of the research needs in this field is provided in a booklet entitled, "Research Needs in Light Frame Construction" by S. K. Suddarth, Purdue University Agricultural Experiment Station, Lafayette, Indiana. This booklet describes the need for research to investigate the static or dynamic mechanical behavior of groups of nails used in joints, and of toothed metal plates used in joists. There is an increased use of adhesive joints in construction, particularly in factory-built and mobile homes; and thus there is a need for continued research on the mechanical behavior and aging properties of adhesive joints.

Research approach: Research efforts to analyze the behavior of nailed joints should be continued and expanded with the objective of elucidating their static and dynamic characteristics. Continued research is also needed on adhesive joints to evaluate and compare different adhesives, to determine their aging properties, and the effect of moisture and temperature changes and to develop quality control methods which would be helpful in maintaining the quality of finished products.

2. Title: Optimized choice of materials for building.

Objective: To investigate the use of alternate materials in building construction to assist architects making optimum choices for wall, floor, and roof systems.

Situation evaluation: When new panel products are developed or when joists or studs become available in alternate materials such as steel, aluminum, or composites, there is a need to evaluate these and compare the possible alternatives. Builders and architects tend to prefer to use traditional or customary methods of construction and materials, but they may be encouraged to use new products if these were tested and compared with conventional materials and the special problems associated with their use were examined and evaluated.

Research approach: Alternative new products could be incorporated into roof, wall, and floor systems on an experimental basis to compare their performance with that of more traditional products. Studies could include evaluation of mechanical properties, fire

performance, thermal insulation, sound transmission, and cost comparisons.

3. Title: Heat transmission through wall, floor, and roof systems.

   Objective: To reduce the energy loss through walls, floors, and roof systems.

   Situation evaluation: The cost of fuel for space heating has increased significantly during the last two years. This problem is particularly severe in the Northeast where heating requirements are extreme. The supplies of known sources of energy are finite. Continued use of large amounts of imported oil results in an unfavorable balance of payments for the United States.

   The use of insulation is probably the least expensive means of reducing heating fuel cost.

   Research approach: An evaluation of the heat losses through various wall and roof systems can be measured to determine U-values. Modifications may be evaluated to reduce heat losses by different insulations, different thicknesses of insulation, and different configurations. The effect of difference of interior and exterior moisture content should be evaluated.

   Windows and doors contribute a significant portion of the heat loss of a building. Research can be directed toward improvement of storm windows and thermopane windows, a comparison of the heat losses of aluminum and wood windows, and an evaluation of the role of wood shutters in reducing heat losses during the night.

4. Title: Sound transmission.

   Objective: To reduce sound transmission through wall, floor, and panel systems.

   Situation evaluation: There is an increasing trend toward the construction of multiple dwellings, particularly in urban centers of the Northeast. The transmission of sound between adjacent apartments on the same floor or on adjoining floors is a severe problem of which all apartment dwellers are aware. The resulting lack of privacy is one of the principal disadvantages to this kind of living. The present economic trends in housing will force larger numbers of people to live in multiple dwellings bringing this problem more into focus.

Research approach: Considerable research has been conducted in the sound transmission field, but this needs to be brought into focus to solve the problem of noise transmission between adjacent housing units. There are in existence today large numbers of apartment buildings with no sound insulation between units. Efforts should be directed toward the establishment of tolerable limits of noise transmission and the means to incorporate these into new structures. Such research may provide a basis for incorporation of suitable standards in building codes.

E. New and improved products - fabricated products.

1. Title: Low-grade lumber utilization.

Objective: To increase the yield of hardwood lumber by developing uses for short lengths of low-grade lumber.

Situation evaluation: At the present time wood is growing at a greater rate than it is being used in the Northeast, however, the size of trees available for harvest is decreasing. With smaller trees the number of wide, long boards available is decreasing. Thus, it is necessary to find uses for short, narrow boards and low-grade lumber.

Research approach: Research efforts would be directed toward finding uses for short length, low-grade lumber in wood products industries of the Northeast. The gluing of short lengths into longer length material by means of serpentine joints is now being investigated at the USDA Forest Products Marketing Laboratory, Princeton, West Virginia. These efforts could be continued and extended to increase the efficient utilization of Northeastem softwoods. Edge-gluing to produce wider boards could also be studied.

F. New and improved products - residue utilization.

1. Title: Urban wood waste.

Objective: To find uses for urban wood waste.

Situation evaluation: Large quantities of urban wood waste are now burned or hauled to dumps. Dead elm trees constitute a significant portion of this, and the wood is frequently sound and could be sawed into lumber or chipped for paper or composite manufacture.

Research approach: The possibility of using dead elm trees and other solid wood wastes to produce lumber or other products should be examined and evaluated. There are instances where sound, high quality lumber has been produced from elm and other logs on a small scale. The possibility of chipping or flaking urban wood waste should also be investigated for use in board and structural member composite products. Alternative uses can range from fuel to timber.

G. New and improved products - chemicals from wood.

1. Title: Chemicals from wood.

Objective: To examine the feasibility of producing methanol, ethanol, sugars, phenols, and furfural from wood as possible substitutes for petroleum-derived chemicals and the feasibility of producing protein from cellulose as a food.

Situation evaluation: In the United States the annual quantity of wood waste is approximately 65 million tons of which 15 million tons are industrial and 50 million are logging residues. The technology for extracting most chemicals from wood is well established since this was utilized during the 50's; but as wood became more expensive and petroleum relatively cheaper, this industry was phased out and replaced by less costly petroleum-based chemicals. The economics are now changing with the recent sharp increase in the cost of petroleum and with improvements in chemical-engineering technology to place wood-based chemicals in a more favorable position. It may be necessary, however, to provide some kind of government subsidy to attract private capital to provide the investment required.

It has been estimated by Goldstein that 50 million tons of wood waste would be required to produce 95 percent of the polymers produced in the country. Waste material which is not suitable for paper or hardboard could be used.

Research approach: The production of methanol by pyrolysis could be reevaluated. In this process charcoal, acetic acid, and other chemicals are produced; the process is exothermic; and present economics may favor this process. The methanol produced could be used as an extender for gasoline thus reducing the dependence on imported petroleum.

The feasibility of the conversion of cellulose to oil should be investigated. Such a conversion would require heat and pressure, and thus the energy balance of such a conversion should be evaluated.

Cellulose may be hydrolyzed to sugars which can be fermented to produce ethanol. The economics of this technology could be examined in the light of recent developments. The ethanol could in turn be used to produce ethylene and butadiene which may be used in the manufacture of synthetic polymers. A comparison could be made between this method and the use of petroleum as a raw material. Similarly, hemicelluloses can be hydrolyzed and converted to furfural. In the whole area of petrochemical substitutes from wood,

the USDA Forest Service is conducting a National Science Foundation funded feasibility study. Research in this area should await the evaluation of results which is due by the end of 1975.

Lignin constitutes a large portion of cellulose waste, and the possibility of producing phenolics from this could be investigated in view of the greatly increased cost and demand of these chemicals. In addition, there may be applications for chemicals already present in lignin and wood extractives without any chemical conversion. Some research effort could be directed toward physical separation of these materials and their possible application.

Research may be continued on the conversion of cellulose to protein as a possible food source.

H. Improved processing.

1. Title: Quality classification of logs and lumber for specific end products.

   Objective: To effectively allocate the available raw material toward specific end products.

   Situation evaluation: Much of the timber growing in the Northeastern area is converted to logs and lumber that are classified as low grade. While useful as a marketing tool, the low standard grades often do not accurately reflect the value of these inputs to the final product. New methods of determining log and lumber value in terms of specific end products are needed.

   Research approach: By bucking long, low-grade logs into short logs of higher quality, a more efficient raw material allocation system can be developed. For allocating short logs (up to 8 feet in length) to the most desirable end products, at least three quality divisions are needed: (1) veneer and clears; (2) sawbolts; and (3) pulpwood.

2. Title: Improved processing techniques for low-grade logs and lumber.

   Objective: To develop processing techniques that will effectively increase the yield of usable components from available Northeastern tree species.

   Situation evaluation: In comparison with other materials, the conversion of wood to finished products (both solid and composite) is energy efficient. Further, the versatility of wood as a source of supply of chemicals and fuel must be included in considerations of future uses. In the face of increased demand and single use land policies, it is possible that the effective supply of wood will be the same in the future as it is today or less. Improved processing techniques would have the effect of extending the available raw material supply and could further reduce the already low energy processing requirements.

   Research is underway using ultrasonic techniques for determining the location of defects. Lumber breakdown equipment controlled by computers is available and more is being developed. Computer programs are available for determining the maximum value of hardwood sawlogs and for maximizing grade mixes for long run manufacturing operations. To a great extent, these developments improve conventional procedures. However, conventional sequences may reflect an economic day gone by where knots, decay, and other defects could be transported, handled, dried, and removed because an abundance

of high-grade lumber made the overall manufacturing process profitable. This may be particularly true for small to medium sized manufacturers.

Research approach: Develop new methods for converting low-grade boards, either long boards from conventional sawmills or short boards from short sawlogs, to pieces ready for assembly. Because of the short lengths of raw material, these new manufacturing sequences will require new processing equipment for breakdown, handling, drying, storing, and assembly.

3. Title: Improved milling and machining.

Objective: To improve the machining of wood by decreasing noise generation, increasing cutting accuracy, improving tool materials, and decreasing saw kerf.

Situation evaluation: There has been and is being conducted a large body of research on the improvement of wood machining. There are many as yet unmet needs. Most lumber is used in cutting thicknesses of four, five, and six quarter. Reducing these thicknesses or improving the precision and smoothness with which lumber is sawn from logs could save many hundreds of thousands of board feet per year. In addition to reducing waste, the present requirements of OSHA to reduce the sound exposure of workers makes it mandatory to carry out research in this area.

Continuing programs could be aimed toward increasing yields by reduction of saw kerf, increasing cutting speeds, and the improvement of materials for cutting tools.

Research approach:

1. A new generation of log breakdown equipment is necessary. It should have the capability of sawing at high speeds while retaining the best sawing accuracy ($\pm$ 1/32") with narrow kerf saws (3/16" maximum). Ultimately, a saw that processes short logs to pieces of specified thickness is desirable.

2. Efforts could be directed toward determining the fundamental reasons for sound generation due to wood machining operations. With an understanding of the mechanism, it may be possible to redesign saws or cutters in a manner to reduce sound generation at the source. In addition, the means of isolating the operator from the machine may be investigated. Sound insulation or absorbing material could be installed around the machine and remote control systems developed which would permit the operator to remain at a

safe distance. An effort could be made to develop more effective protective devices to muffle and reduce sound levels reaching the ear of the operator.

3. The efforts to reduce saw kerf, increase machining speeds, and to improve cutting materials should be continued. Efforts in the use of tape-controlled machining methods should be expanded to improve production efficiency.

4. Title: Improved drying processes.

Objective: To increase the speed of and reduce the defects resulting from the drying process.

Situation evaluation: The Northeastern area contains an abundance of refractory hardwoods and softwoods. With present drying methods and particularly during periods of high demand, there is a considerable loss of volume and grade. Current research in the area includes studies of moisture diffusion and strain models; the development of least cost techniques that balance drying time against grade losses; the study of remote moisture and strain sensing techniques; studies of computer assisted drying systems; and economic studies of the use of low temperature kilns as a middle step between green and kiln dried lumber.

Research approach: There should be fundamental studies directed toward developing a satisfactory unified drying theory. Once this has been accomplished, hardwood drying schedules should be reexamined and modified for more efficient energy and capital utilization. Of specific interest is faster, damage free drying of thick material and material containing juvenile tissue.

Energy sources for kiln drying should also be explored further. Solar energy might provide at least some of the B.t.u.'s required. Low enthalphy energy sources should also be investigated.